

NICER

Neutron star Interior Composition Explorer

NICERDAS Calibration Guide

20180226

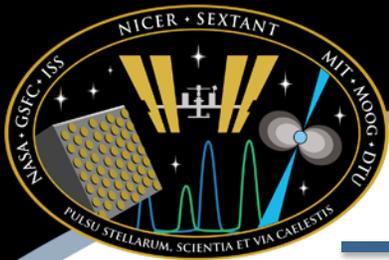
Craig Markwardt



MIT KAVLI
INSTITUTE



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NICERDAS Calibration Summary

- This presentation provides basic calibration caveats of the CALDB released 20180226
- This CALDB version has been applied to the data processed for the 1st data public release March 2018

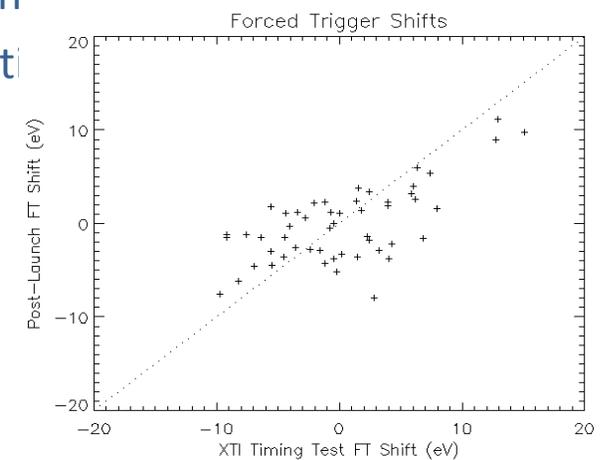
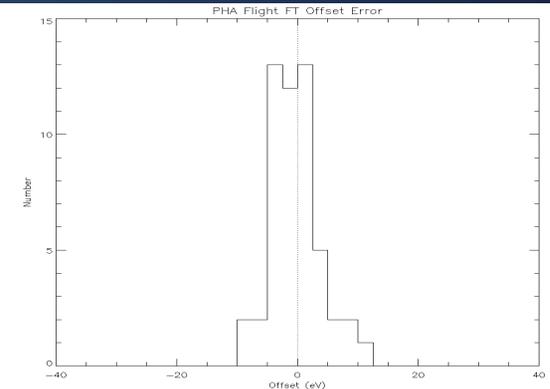


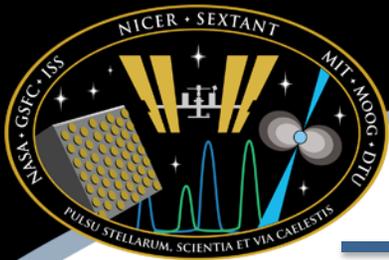
Major Improvements: Gain Calibration

- NICER gain calibration is as good as time will allow
 - Per-detector offsets now ~ 5 eV or less
 - Temperature effects accounted for using method of MIT
 - Improved PI_FAST calibration
 - Energy range increased to 18 keV

- Major challenge discovered after Jan AAS meeting: the energy scale has shifted since ground calibration
 - Evidence for shifts during ground testing and post-launch
 - Forced the team to consider a phenomenological correction calibration
 - This calibration model is known as “RATIONAL2”

- Detailed investigation of ballistic deficit effect by MIT team for slow and fast channels
 - < 1.5 eV in 0-6 keV band (slow channel)



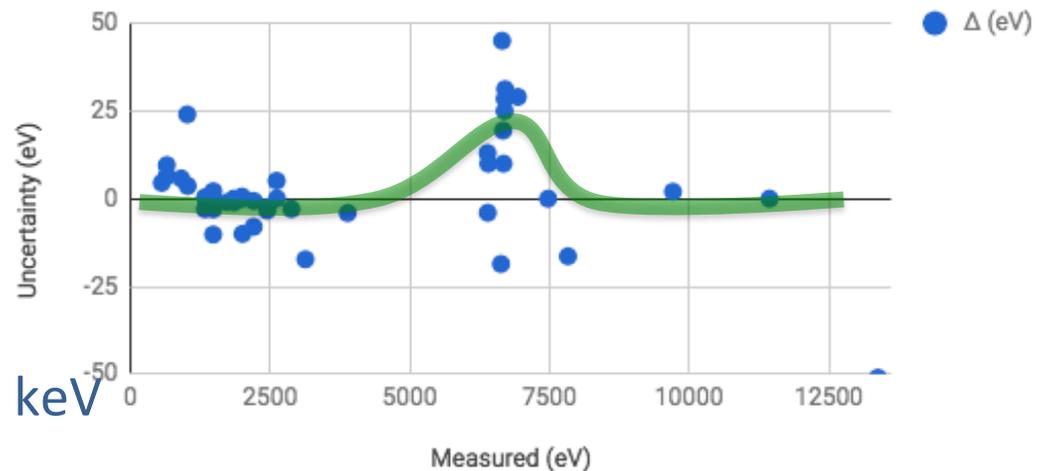


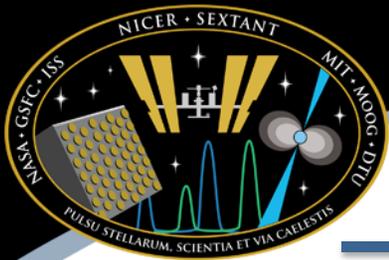
Major Improvements: Gain Performance 1

- Generally performance is excellent across multiple temperature and lighting conditions
- Team tested against many astrophysical targets of different types
 - Lines 0.6-2.7, 6.4-7.5 keV keV
- Also used SAA data
 - Gold/Nickel fluorescence at 1.4, 1.8, 7.5, 8.3, 9.5, 11.5, 13.3 keV
- Evidence of deviation in 5-7 keV range of about +20-30 eV
 - Difficult to adjust for without disturbing energy scale at other energies
 - **Analysts should be very careful about claiming red/blue shifts of 10s of eV in this range**

Residual Energy Shifts

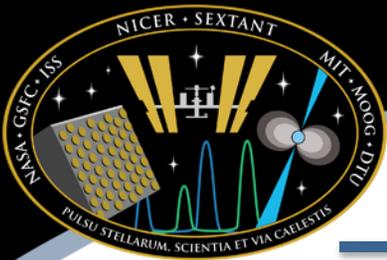
NICER Calibration Shifts (RATIONAL2)





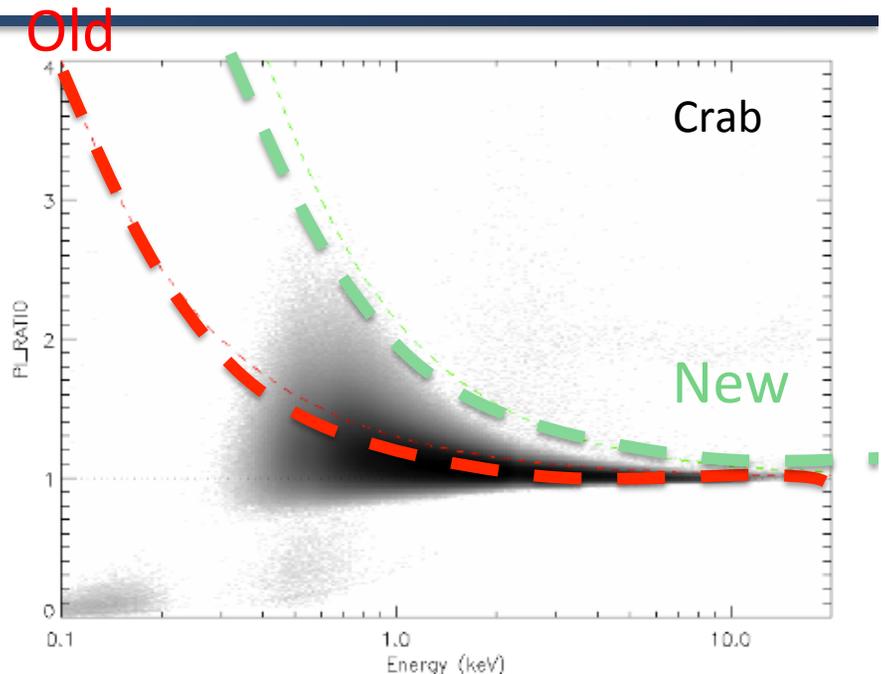
Major Improvements: Gain Performance 2

Dataset	Feature	Meas	Expect	Δ (eV)	σ (eV)	Comments
GX301-2	FeKa	6394.97	6399	-4	5.0	MikeL Analysis, +/- 5 eV
Perseus	Mg_XII	1490	1488	2	3.5	MikeL Analysis, +/- 3.5 eV
Perseus	Si_XIV	2004	2004	0	3.5	MikeL Analysis, +/- 3.5 eV
Perseus	S_XVI	2625	2620	5	5.1	MikeL Analysis, +/- 5.1 eV
Perseus	Fe_wxyz	6693	6673	19	3.3	MikeL Analysis, +/- 3.3 eV
Perseus	Ni	7818	7835	-16	15.0	MikeL Analysis, +/- 15 eV
WR 140	Fe_XXV	6740	6709	31		Mike C analysis; corrected for redshift (-393 km/s) derived from HEG spectrum
Eta Car	Fe_XXV	6730	6701	29		Mike C analysis; corrected for redshift (-66.7 km/s) derived from HEG spectrum
Cas_A	Mg_Xi	1346	1346	0	1.0	MikeL Analysis, +/- 1 eV; NOTE Cas A has redshifts of +/- 1000 km/s ~ 20 eV
Cas_A	Mg_XII	1474	1474	0	3.0	MikeL Analysis +/- 3 eV
Cas_A	Si_XIII	1857	1858	-1	0.2	MikeL Analysis +/- 0.2 eV
Cas_A	Si_XIV	2005	2005	1	1.0	MikeL Analysis +/- 1 eV
Cas_A	S_XIII	2200	2208	-8	1.5	MikeL Analysis +/- 1.5 eV
Cas_A	Si_XV	2448	2452	-3	1.0	MikeL Analysis +/- 1 eV
Cas_A	S_XVI	2626	2626	0	5.0	MikeL Analysis +/- 5 eV
Cas_A	S_XVI	2882	2885	-3	4.0	MikeL Analysis +/- 4 eV
Cas_A	Ar_XVII	3118	3136	-17	2.0	MikeL Analysis +/- 2 eV
Cas_A	Ca_XIX	3888	3892	-4	4.0	MikeL Analysis +/- 4 eV
Cas_A	Fe_XXV	6616	6635	-19	5.5	MikeL Analysis +/- 5.5 eV; actual remnant has ~1000 km/s Dopler ~ 20 eV
HR 1099	Fe_XXV	6725	6700	25		Mike C Analysis: assumes real redshift of Fe XXV line = 0 km/s
Coma	Fe_XXV	6691	6681	10	15.0	MikeL Analysis +/- 15 eV
Coma	Fe_XXVI	6965	6936	29	24.0	MikeL Analysis +/- 24 eV
E0102	O_VIIa	570	565	5		MikeL Analysis
E0102	O_VIIb	665	655	10		MikeL Analysis
E0102	Ne_IXa	919	913	6		MikeL Analysis
E0102	Ne_IXb	1033	1029	4		MikeL Analysis
E0102	Mg_XI	1335	1338	-3		MikeL Analysis
N132D	Mg_Xi	1340	1340	0	2.0	MikeL Analysis
N132D	Mg_XII	1475	1485	-10	6.0	MikeL Analysis
N132D	Si_XIII	1860	1860	0	4.0	MikeL Analysis
N132D	Si_XIV	2000	2010	-10	10.0	MikeL Analysis
N132D	S_XIII	2213	2213	-1	15.0	MikeL Analysis
N132D	Si_XV	2449	2452	-3	8.0	MikeL Analysis
Cen X-3	Fe K	6409	6396	13		Mike C analysis - Fe K line energy from fit to heg spectrum tgcat/obs_7511_tgid_4068
Cen X-3	Fe_XXV	6701	6656	45		Mike C analysis - Fe XXV line in heg spectrum
Vela X-1	Fe K	6417	6407	10		Mike C - Fe K line energy derived from HEG tgcat obs_1928_tgid_5097
SAA	Al Ka	1483	1486	-3	2.0	CM
SAA	Si Ka	1739	1740	-1	4	CM
SAA	Ni Ka	7478	7478	0	2	CM
SAA	Au La	9715	9713	2	1	CM
SAA	Au Lb	11442	11442	0	2	CM; 60 eV extra broadening
SAA	Au Lg	13330	13381	-51	25	CM; really dodgy
UX Ari	O VIII	660.2	653.8	6.4	20.0	Mike C Analysis ux_ari-rational2.pha; line velocity (+89 km/s) determined from MEG -1 order spectrum
GT Mus	Ne X	1046	1022	24.0		Mike C - line velocity uncertain



Major Improvements: Trumpet Cut

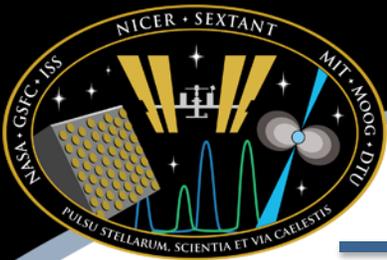
- Trumpet cut is designed to exclude background events that interact at outer edges of detectors
 - Relies on “ballistic deficit” effect which primarily shows up in the fast channel
 - $PI_RATIO = PI/PI_FAST$ can discern this effect
 - “Trumpet” shape occurs because of read-out noise in denominator of ratio at low energies
 - Standard trumpet intended to exclude bad data
- However, in optical loading conditions (orbit day) additional noise in the PI_FAST channel broadens the trumpet beyond typical expectations
 - See example of Crab above
 - Spectral effect will be to truncate counts at low energies between 600-1100 eV where fast channel threshold is transitioning
- New trumpet definition is “120-1” and accomodates bright optical condition





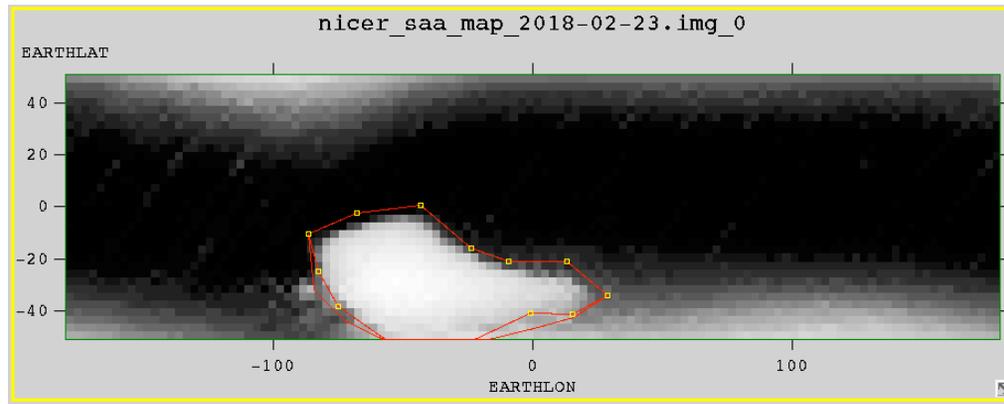
Major Improvements: Time Calibration

- NICER calibration now includes timestamp correction
 - NICER detector system known to have instrumental delays
 - ~440 nsec – fast channel (fast-only or fast+slow)
 - ~950 nsec – slow channel (slow-only)
 - New task nicertimecal compensates for these delays by adjusting TIME column on per-event basis
- Known absolute timestamp offset of +1 second
 - Now understood as improperly documented behavior of hardware clock system
 - Correction implemented as TIMEZERO keyword for event files, GTIs and filter files
 - Extractor will automatically adjust time values using TIMEZERO when creating light curves
 - Team member custom software will need to honor TIMEZERO

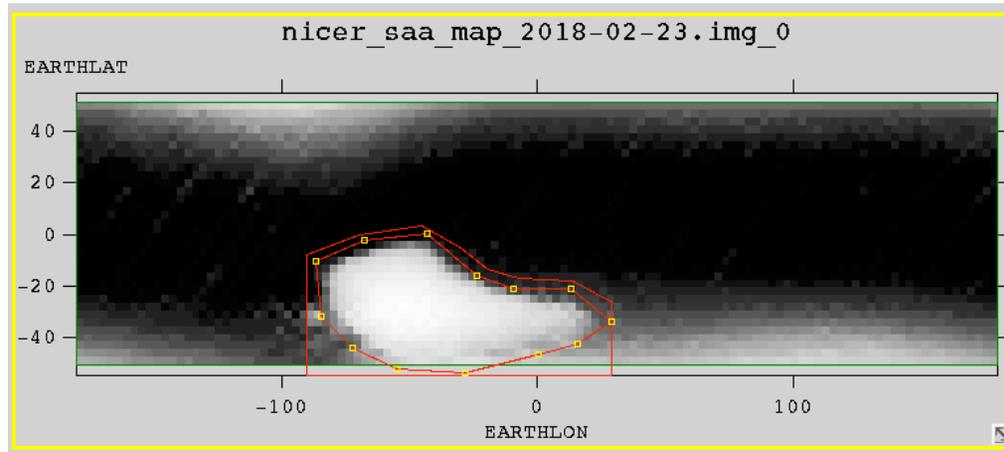


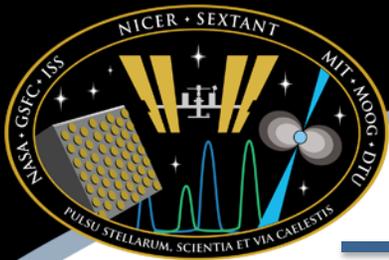
Improvements: SAA Contour

- Standard NICER_SAA contour has been enlarged slightly on the southern edge



- Also including in CALDB a “fat” SAA for users very sensitive to background





Calibration & Software: Future Work

- Items for work after public release
 - Improve gain calibration around 5-7 keV range
 - ARF calculator tool based on actual pointing and roll angle
 - RMF calculator tool based on optical loading conditions (broadens resolution)